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Impact of police body armour and equipment on mobility

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A B S T R A C T

Body armour is used widely by law enforcement and other agencies but has received mixed reviews. This study examined the influence of stab resistant body armour (SRBA) and mandated accessories on physiological responses to, and the performance of, simulated mobility tasks. Fifty-two males (37 ± 9.2 yr, 180.7 ± 6.1 cm, 90.2 ± 11.6 kg, VO_{2max} 50 ± 8.5 ml kg^{-1} min^{-1}, BMI 27.6 ± 3.1, mean ± SD) completed a running VO_{2max} test and task familiarisation. Two experimental sessions were completed (≥4 days in between) in a randomised counterbalanced order, one while wearing SRBA and appointments (loaded) and one without additional load (unloaded). During each session participants performed five mobility tasks: a balance task, an acceleration task that simulated exiting a vehicle, chin-ups, a grappling task, and a manoeuvrability task. A 5-min treadmill run (zero-incline at 13 km·h^{-1}, running start) was then completed. One min after the run the five mobility tasks were repeated.

There was a significant decrease in performance during all tasks with loading ($p < 0.001$). Participants were off-balance longer; slower to complete the acceleration, grapple and mobility tasks; completed fewer chin-ups; and had greater physiological cost (↑ $\%HR_{max}$, ↑ $\%VO_{2max}$, ↑ RER) and perceptual effort (↑ RPE) during the 5-min run. Mean performance decreases ranged from 13 to 42% while loaded, with further decreases of 6–16% noted after the 5-min run. Unloaded task performance was no different between phases.

Wearing SRBA and appointments significantly reduced mobility during key task elements and resulted in greater physiological effort. These findings could have consequences for optimal function in the working environment and therefore officer and public safety.

1. Introduction

Law enforcement officers have traditionally worn and carried various protective and functional equipment required in the discharge of their duties (Hooper, 1999; Stubbs et al., 2008). For the New Zealand Police, the duty belt and mandated appointments (equipment currently consisting of a duty belt, radio, extendable baton, pepper spray, handcuffs, a personal protection kit and a torch) weigh approximately 3.5 kg (Stab Resistant Body Armour Introduction and Guidelines, 2007). Body armour (e.g. stab resistant body armour, SRBA) is used widely by law enforcement and other agencies internationally. In 2007, SRBA was introduced to all frontline New Zealand Police, purportedly in response to escalating crimes of violence, and to reduce officer fatalities (Stab Resistant Body Armour Introduction and Guidelines, 2007; Wallwork, 2010). While the SRBA (2.7–3.8 kg depending on size) provides protection from stabbing, blunt trauma, and small calibre bullets, it has been suggested that the SRBA and belt unit negatively affect police physical performance (Hooper, 1999; Stubbs et al., 2008).

Although there is a wealth of literature exploring the impact of added load (backpacks) on human performance (Knapik et al., 1996), few studies have been designed to assess the effect of body armour on task elements typically encountered in policing. Most research involves analysis of military based tasks using heavier specialised military body armour, finding that it adversely affects mobility, strength, speed, balance and physiological strain (Dorman and Havenith, 2009; Larsen et al., 2011; Ricciardi et al., 2008). The weight and rigidity of SRBA along the length of the torso may also hinder an individual's ability to move efficiently and correct loss of balance (Hooper, 1999; Stubbs et al., 2008). Anecdotal police reports and officer interviews within New Zealand and the United Kingdom suggest that SRBA and appointments restrict job related mobility during a number of work related tasks. Tasks cited were running, pursuing, rapidly exiting vehicles and scuffling or grappling with an offender. More mundane tasks, such as

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manoeuvring or lifting their body weight, carrying, climbing over objects, balancing, and changing a car wheel, were also reportedly affected (Bonneau and Brown, 1995; Collingwood et al., 2004; Hooper, 1999; Stubbs et al., 2008; Wallwork, 2010).

The purpose of this study was to explore and provide information on the influence that the wearing of SRBA and mandated appointments has on physiological markers of effort and performance during the completion of simulated mobility tasks. We hypothesised that wearing the SRBA and appointments would negatively impact all mobility tasks and increase the physiological effort of movement. Given that failure to complete critical tasks in police work could have potentially fatal consequences for police officers, their work colleagues, and the public they serve, this research is timely and necessary.

2. Methods

2.1. Participants

Fifty-three male participants were recruited from the New Zealand Southern Region District Police force with assistance from a Southern Region Police physical education officer. The demanding testing required that participants be physically active with no history of cardiovascular disease or neurological deficits, and free of musculoskeletal injury. Participants were asked to abide by test preparation guidelines and keep pre-testing physical activity, sleep patterns and diet consistent between test sessions.

2.2. Baseline session

Participants completed a 10–12 min incremental treadmill test to identify their maximal aerobic fitness (VO_{2max}), with oxygen uptake (VO_2), respiratory exchange ratio (RER) and heart rate (HR) recorded throughout. The test ended at volitional fatigue, or when all of the following criteria (Howley et al., 1995) were realised: (i) a plateau in VO_2 with increases in external work (ΔVO_2 <150 ml·min^{-1} at VO_{2peak}) (ii) RER >1.1, and (iii) HR reaching $\pm$ 10 b·min^{-1} of age-predicted maximum (220-age). Participants' age, height and body mass were recorded. Following the test, participants were fully familiarised with testing procedures and practiced all five mobility tasks (see Section 2.3) three times each while both loaded and unloaded. This familiarisation and practice ensured test consistency and suitable technique were achieved.

2.3. Mobility task sessions

Wearing exercise shoes and clothing, participants completed two identical experimental sessions in a randomised and counterbalanced order. One session was conducted carrying added load (loaded, fitted SRBA plus weight representative of a standard police duty belt and appointments, 7.65 kg $\pm$ 0.73, mean $\pm$ SD), while the other was completed without additional load (unloaded). Sessions were completed under the same conditions within an eighteen day period, with at least four days between sessions. It was not possible for all participants to complete their testing at the same time of day due to availability and shift work schedules.

During each session, participants completed five mobility tasks (initial phase) that were selected based on job task analyses from the literature (Bonneau and Brown, 1995; Hooper, 1999; Stubbs et al., 2008) and a review of the New Zealand Police Physical Competency Test (Handcock and Dempsey, 2011) to represent mobility challenges encountered during police work. Time between the tasks were standardised based on expected exertion (45 s after the lower exertion balance and acceleration tasks and 90 s after the higher exertion chin-ups, grapple and manoeuvrability tasks), but also to adhere to data recording and session time constraints. After the fifth mobility task, participants rested for 5 min (final 3 min seated) and were connected to a metabolic cart (Cosmed, CPET, Rome, Italy). They then completed a 5-min run on a zero grade treadmill at 13 km·h^{-1} commencing from a running start. While the amount of job related running for police is difficult to quantify, the treadmill run was an attempt to replicate a near maximal running effort that may present a worst-case policing scenario (Bonneau and Brown, 1995; Collingwood et al., 2004; Strating et al., 2010). The 13 km·h^{-1} treadmill speed was based on the mean running speeds attained during the run section of the New Zealand Police Physical Competency Test (Handcock and Dempsey, 2011). Measures of HR (Polar S-810i, Kempele, Finland), VO_2, and RER were recorded and averaged over the final min. A rating of perceived exertion (RPE) score (Borg 6–20) was recorded during the final 20 s of the run. On run completion, participants rested for 1 min before repeating the five mobility tasks with identical rest times (repeat phase). To avoid possible performance bias, participants were blinded to their initial phase results.

The mobility tasks were:

(1) a timed balance task, standing on a stabilometer platform with feet shoulder width apart. Initial balance was achieved and as soon as the participant's hands were released from supports the test began. The objective was to keep the platform balanced against lateral excursions (left and right edges out of contact with the ground) for 30 s. Time off-balance was recorded as the total time the platform was in contact with the ground.
(2) an acceleration task to simulate exiting a vehicle. Participants began this task sitting in a floor mounted car seat (Nissan Skyline GTS, seat bottom 30 cm high) with their feet flat on the ground. On "GO" they stood without arm assistance, pivoted 90° to the right and sprinted 2.85 m through a set of opto-reflective timing gates.
(3) as many successive standard chin-ups as possible (underhand grip). Upper body strength or strength endurance has been indicated as an important element in a number of police job task analyses (Bonneau and Brown, 1995; Collingwood et al., 2004; Handcock and Dempsey, 2011).
(4) a grapple task. On "GO", participants raised a cylindrical 'grappling bag' (G_{BAG}; weight 64.5 kg, length 155.25 cm, diameter 37.10 cm) to vertical position. Grasping the middle of the G_{BAG}, they then lifted the G_{BAG} 0.75 m onto a wooden platform (89 $\times$ 122 cm) demarcated into two target zones (each 45 $\times$ 56.7 cm) separated by a 70 mm high by 65 mm wide strip (Fig. 1). The G_{BAG} was then lifted and moved twice over the strip, touching the bag down in each target zone, before being lifted off the platform, tilted down and dragged 4.5 m until the distal end of the bag crossed a line and the timer was stopped.

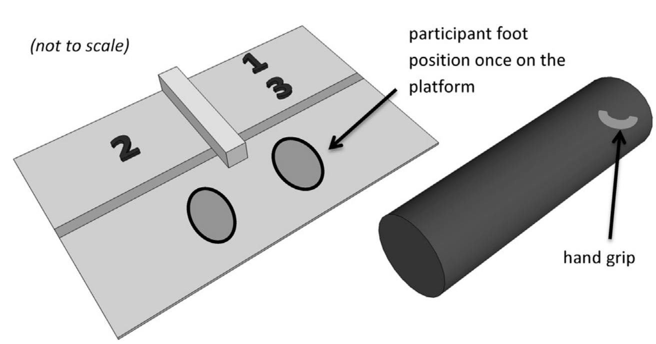

Fig. 1. Schematic diagram of the wooden platform and grappling bag (G_{BAG}) used for the grappling task. *Note.* The numbers in each target zone indicate where the G_{BAG} was sequentially touched down.

(5) a manoeuvrability task. Participants started in a push-up position. On "GO", they dropped their chests to the floor, rolled to their left, pushed hard upwards to perform a clapping push up, dropping back to the floor. They then rolled back to their right before pushing back up to their starting position. Participants then pivoted around their feet, walking their hands around to complete a full anticlockwise circle. Once back at their start position, participants then military crawled forward 3 m using only their elbows (no lower limb assistance permitted) until both elbows entered a marked square. They then stood to press a switch and stop the timer (Fig. 2).

2.4. Data analysis

Participants' 5-min run HR and VO_2 data were normalised as a percentage of values recorded during their maximal treadmill test. Some task results are expressed as percentage difference between the means for clarity. A linear mixed model analysis (SPSS-19.0 Inc. – Windows) was individually conducted on each of the mobility task scores and 5-min run measurements (as dependant variables) with loading and test phase (before or after the 5-min run) as repeated effects (i.e. loading, test phase, loading $\times$ test phase) for each task and participants grouped as a random effect. A compound symmetry heterogeneous covariance matrix best suited the data and was thus assumed best for the covariance structure. Estimated marginal means ($\pm$SD) and 95% confidence limits were calculated and compared with a Sidak confidence interval adjustment. Residuals were examined for serial correlation, heteroscedasticity and normality, estimated models were deemed satisfactory.

3. Results

One participant was excluded prior to data collection due to a recent musculoskeletal injury, leaving fifty-two participants that completed all required testing. Participant characteristics (Table 1) represented a broad range of ages, body sizes (BMI), and cardiorespiratory fitness levels. For example, VO_{2max} test scores ranged from 31.53 to 67.69 $ml \cdot kg^{-1} \cdot min^{-1}$ and BMI values from 20.71 to 35.62 $kg \cdot m^2$. During maximal testing all participants' heart rates were within 10 $b \cdot min^{-1}$ of their age predicted maximum heart rate (APMHR, 220-age) and RER >1.1.

Table 1
Participant characteristics and graded maximal treadmill test data.

	Mean	SD	Range
Characteristic			
Age (yr)	37	9.16	22–53
Height (cm)	180.68	6.12	165.50–194.1
Weight (kg)	90.21	11.59	68.25–114.50
BMI ($kg \cdot m^2$)	27.61	3.09	20.71–35.62
VO_{2max} test			
VO_{2max} ($L \cdot min^{-1}$)	4.46	0.67	2.97–6.34
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	50.00	8.46	31.53–67.69
HR_{max} ($b \cdot min^{-1}$)	187	8.95	171–209
RER_{max}	1.34	0.08	1.10–1.50
% APMHR	102.65	4.49	92.75–114.44

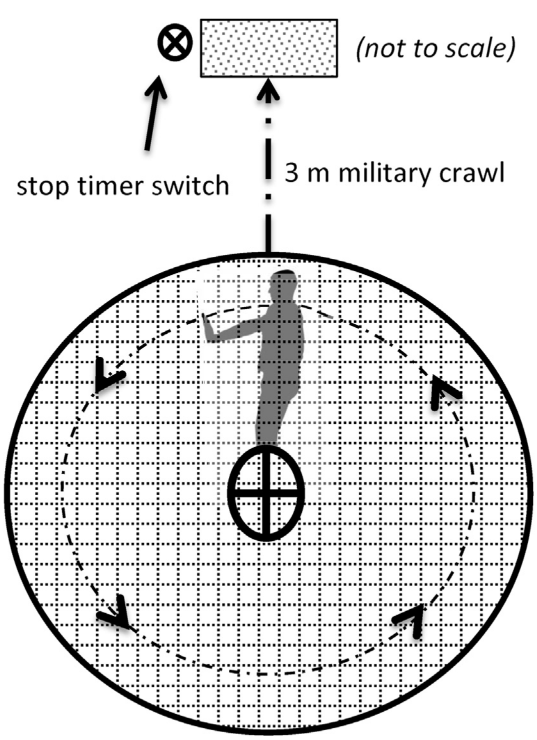

Fig. 2. Schematic diagram of the hand walking and military crawl portions of the mobility task.

3.1. Mobility tasks

Two participants (VO_{2max} scores of 31.53 and 34.05 $ml \cdot kg \cdot min^{-1}$ – the lowest in the testing sample) were unable to complete the loaded 5-min run at the specified speed and completed the final 40–50 s with the treadmill speed lowered to 12 $km \cdot h^{-1}$. While this a priori protocol change did not appear to influence their physiological measurements, 5-min run data from these participants were omitted from the statistical analysis. The mobility tasks were negatively affected by loading with mean decreases in performance ranging from 13 to 42% ($p < 0.001$). Participants worked significantly harder (↑%HR_{max}, ↑%VO_{2max}, ↑RER and ↑RPE; $p < 0.001$) while loaded during the 5-min run. Mobility task performance was further reduced (6–16%, $p < 0.001$) after the run but only while participants were loaded – there were no differences in unloaded task performance between the different phases (Table 2).

4. Discussion

Anecdotal police reports and officer interviews within New Zealand and the United Kingdom claim that SRBA and appointments restrict functional mobility during a number of work related tasks (Hooper, 1999; Stubbs et al., 2008). This is the first study to directly examine the influence of added load (SRBA and weight representative of appointments and duty belt) and high to moderate intensity exercise on the performance of simulated mobility tasks. Tasks were designed and selected to represent mobility challenges typically encountered in law enforcement and influenced by the movement restrictions, additional weight, and physiological effort imposed by the SRBA. The study incorporated a relatively large number of participants, with broader ranges of fitness level, body size and age, allowing for a more representative sample. As hypothesised, mobility task performance was adversely affected by added load and this effect was further amplified by high to moderate intensity exercise.

Research into added load has been conducted with the military and was therefore designed to explore the physiological impact of heavier loads differently distributed (primarily backpack and some military body armour), and during prolonged slow to moderate paced walking (Birrell and Haslam, 2010; Knapik et al., 2004; Ricciardi et al., 2008). The present study used a 5-min run to simulate an abrupt running pursuit task. Participants physiological

Table 2
The influence of loading on mobility and 5-min run tasks for the initial phase and repeat (tasks i-iv repeated after the 5-min run) phase.

Task	Initial phase						Repeat phase					
	Unloaded			Loaded			Unloaded			Loaded		
	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI
i. Time off balance (s)	5.7	1.9	5.16–6.23	8.12[a]	2	7.55–8.68	5.79	1.9	5.28–6.31	9.79[a,b]	2.7	9.04–10.55
ii. Acceleration TTC (s)	1.67	0.2	1.62–1.71	1.95[a]	0.2	1.89–2.01	1.71	0.2	1.66–1.76	2.17[a,b]	0.3	2.09–2.25
iii. Chin-ups completed	8.21	4.8	6.9–9.6	5.35[a]	3.9	4.3–6.4	7.63	4.9	6.3–9.0	4.37[a,b]	3.7	3.3–5.4
iv. Grapple TTC (s)	11	1.8	10.50–11.50	12.89[a]	2.2	12.28–13.51	11.13	1.8	10.63–11.64	13.85[a,b]	2.4	13.15–14.54
v. Mobility TTC (s)	15.85	2	15.18–16.28	18.16[a]	2.4	17.48–18.85	15.85	2	15.30–16.40	19.34[a,b]	2.6	18.61–20.07
Five min run:												
$\%HR_{max}$ ($b \cdot min^{-1}$)	83.5	6.9	81.6–85.4	89.9[a]	5.8	88.3–91.5						
$\%VO_{2max}$ ($L \cdot min^{-1}$)	81.3	5.8	79.7–82.9	90.3[a]	4.2	89.1–91.4						
$\%VO_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	81.5	6	79.8–83.2	84.3[a]	5	82.9–85.7						
RER (VCO_2/VO_2)	0.94	0.11	0.91–0.97	1.05[a]	0.11	1.02–1.08						
RPE_{final}	13.5	2	12.9–14.0	17.1[a]	1.7	16.6–17.6						

TTC, time to complete; 95% CI, 95% confidence interval; HR, heart rate; VO_2, oxygen consumption; RER, respiratory exchange ratio.
[a] Loaded significantly different from unloaded, $p < 0.001$.
[b] Loaded repeat significantly different from loaded initial, $p < 0.001$.

(VO_2, HR, RER) and perceptual (RPE) measures of effort during this high to moderate intensity run significantly increased while wearing SRBA and added load representative of equipment on a duty belt. Increases in oxygen consumption and heart rate have also been reported with heavier military body armour at various walking speeds (Majumdar et al., 1997; Ricciardi et al., 2008). Moreover, two participants with the lowest cardiovascular fitness scores in this study failed to complete the loaded 5-min run and arguably experienced an increased effect, or had less aerobic functional reserve available to them while wearing the body armour.

Most research on added load has included investigation of balance as postural stability or sway, using centre of pressure measurements (Rugelj and Sevšek, 2011; Schiffman, 2004). The present study measured dynamic balance using a stabilometer that required participants to actively compensate for lateral disruptions in postural stability. This task is arguably more relevant to police work, in which surface, environmental and task constraints are more likely. Findings from the present study indicate that participants' ability to perform a dynamic balance task under load is significantly compromised when preceded by intense exercise. Individuals compensate in various ways to postural challenges. Compensatory movements (e.g. with the torso and arms) would typically aid in countering perturbations in dynamic balance. Since the SRBA-appointments belt unit form a solid connection between the waist and upper body, torso mobility and flexibility is more likely to be restricted (Stubbs et al., 2008). Any movement restrictions could disturb a preferred compensatory action to avoid loss of balance. The decrease in loaded balance during the repeat phase may be the result of cumulative fatigue from preceding tasks and the 5-min run that could evoke disturbances in visual, vestibular and neuromuscular control (Bisson et al., 2010; Gribble and Hertel, 2004; Schneiders et al., 2012).

The present study demonstrates that SRBA and appointment weight significantly slowed participants' time to exit a low car seat, turn, and sprint by a mean of 16%. The time to complete a simulated ground mobility task was also 14% slower when participants were loaded. Both tasks require participants to manoeuvre their body weight, and the added weight of the SRBA and appointments impede this ability. These effects are probably due to reduced upper body mobility and increased external weight carried (Hooper, 1999; Stubbs et al., 2008). Such factors act to increase momentum, meaning individuals have to overcome greater inertia to initiate movement and then apply more effort to slow momentum and change direction. Time to complete the grapple task was 15% slower on average when participants were loaded. This apparent difficulty manipulating the G_{BAG} could be due to decreased upper body mobility as a result of SRBA stiffness, movement restriction and bulkiness, which is in agreement with suggestions presented by law enforcement (Hooper, 1999; Stubbs et al., 2008) and military (Dorman and Havenith, 2009) reports.

Participants completed 42% fewer chin-ups while loaded, indicating that upper body performance is compromised while wearing SRBA and equipment. This mean decrease was less than that observed by Ricciardi et al. (2008), in which 17 male military participants completed 61% fewer chin-ups while wearing ballistic 'interceptor' body armour weighing 10 kg. The present study used a considerably larger sample size with broader ranges for age, body size and fitness level, and a wider range of chin-up scores were observed amongst participants in response to loading. Notably, most participants completing two or fewer chin-ups when unloaded could typically not perform any chin-ups while loaded. In terms of police work, it could be argued that the focus should be on these participants, as their lower threshold for upper body strength could prove disadvantageous in situations where an officer needs to pull or manoeuvre their body weight (e.g. climbing over a wall, ledge, or fence) primarily using their upper body strength.

When interpreting and generalising data from this study, it is important to recognise that the simulated mobility tasks employed were all laboratory-based. Thus, while providing valuable information in a controlled setting on participants' movement restriction, physiological effort, and the ability to quickly manoeuvre their body weight, the tasks may not account for environmental, motivational or personal constraints potentially encountered in law enforcement. Although participants in this study represented a wide range of fitness levels, body sizes and ages, due to convenience sampling and selection criteria employed, our participants may not be fully representative of all New Zealand police. In particular, the sample did not represent all ethnicities, and the study criteria excluded female participants. If a wider range of participants had been used in this respect, including female officers and more ethnic groups, the results may have been different.

In summary, this study demonstrates the mobility restriction and physiological cost imposed when wearing SRBA and appointments. While dependant on many factors, including the specific law enforcement situation faced, the impact on task performance may have implications for officer function and safety, with the potential for earlier onset of fatigue in individuals with lower cardiovascular fitness. Knowledge of these effects should provide further insight into particular tasks and critical work scenarios, enabling organisations to make better informed decisions regarding employee physical performance, testing, and safety. Other strategies could include changes to training procedures and policy, an increased emphasis on safe technique for key tasks, and an overall reduction in unnecessary weight carried. Future research could further explore the impact of individual factors (i.e. gender, fitness, age and body mass or composition) on the magnitude of loading effects.

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References

Birrell, S., Haslam, R., 2010. The effect of load distribution within military load carriage systems on the kinetics of human gait. Appl. Ergon. 41, 585–590.
Bisson, E.J., Chopra, S., Azzi, E., Morgan, A., Bilodeau, M., 2010. Acute effects of fatigue of the plantarflexor muscles on different postural tasks. Gait Posture 32, 482–486.
Bonneau, J., Brown, J., 1995. Physical ability, fitness and police work. J. Clin. Forensic. Med. 2, 157–164.
Collingwood, T.R., Hoffman, R., Smith, J., 2004. Underlying physical fitness factors for performing police officer physical tasks. Police Chief 71, 32–37.
Dorman, L., Havenith, G., 2009. The effects of protective clothing on energy consumption during different activities. Eur. J. Appl. Physiol. 105, 463–470.
Gribble, P.A., Hertel, J., 2004. Effect of lower-extremity muscle fatigue on postural control. Arch. Phys. Med. Rehabil. 85, 589–592.
Handcock, P.J., Dempsey, P.C., 2011. A Review of the New Zealand Police Physical Competency Test (Technical Report). School of Physical Education, University of Otago, New Zealand, Dunedin.
Hooper, R.H., 1999. Why Do Police Officers Leave Their Body Armour in the Cupboard? Contemporary Ergonomics. Taylor & Francis, London, pp. 358–363.
Howley, E., Bassett, D., Welch, H., 1995. Criteria for maximal oxygen uptake: review and commentary. Med. Sci. Sports Exerc. 27 (9), 1292–1301.
Knapik, J., Harman, E., Reynolds, K., 1996. Load carriage using packs: a review of physiological, biomechanical and medical aspects. Appl. Ergon. 27, 207–216.
Knapik, J., Reynolds, K., Harman, E., 2004. Soldier load carriage: historical, physiological, biomechanical and medical aspects. Mil. Med. 169, 45–56.
Larsen, B., Netto, K., Aisbett, B., 2011. The effect of body armor on performance, thermal stress, and exertion: a critical review. Mil. Med. 176, 1265–1273.
Majumdar, D., Srivastava, K.K., Purkayastha, S.S., Pichan, G., Selvamurthy, W., 1997. Physiological effects of wearing heavy body armour on male soldiers. Int. J. Ind. Ergon. 20, 155–161.
Ricciardi, R., Deuster, P., Talbot, L., 2008. Metabolic demands of body armor on physical performance in simulated conditions. Mil. Med. 173, 817–824.
Rugelj, D., Sevšek, F., 2011. The effect of load mass and its placement on postural sway. Appl. Ergon. 42, 860–866.
Schiffman, J., 2004. Load Carriage: Quiet Stance, Postural Sway and Balance Recovery. Natick Soldier Systems Center, Natick, MA.
Schneiders, A.G., Sullivan, S.J., Handcock, P.J., Gray, A., McCrory, P.R., 2012. Sports concussion assessment: the effect of exercise on dynamic and static balance. Scand. J. Med. Sci. Sports 22, 85–90.
Stab Resistant Body Armour Introduction and Guidelines, 2007. New Zealand Police National Headquarters, Wellington.
Strating, M., Bakker, R., Dijkstra, J., Lemmink, K., Groothoff, J., 2010. A job-related fitness test for the Dutch police. Occup. Med. (Lond.) 60, 255–260.
Stubbs, D., David, G., Woods, V., Beards, S., 2008. Problems associated with police equipment carriage with body armour, including driving. Contemp. Ergon., 23–28. Taylor & Francis, London.
Wallwork, G., 2010. Health and Safety Report: SRBA Vests. New Zealand Police, Wellington.